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NEUROELECTRIC CORRELATES OF PREFERRED SEXUAL CONTENT AND THEIR IMPLICATIONS FOR FORENSIC PSYCHIATRY

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ABSTRACT

Neuroscientific methods have made significant contributions to the modern world. In the past decades research has shown how neuroscientific knowledge is used for applications in medical diagnostics and has even influenced the practice of law, where the interaction of the mind, brain and behavior becomes increasingly decisive. Apart from basic questions about free will or the nature of empathy, researchers in forensic psychiatry are interested in practical applications of neuroscientific methods for the use within forensic assessments admissible in criminal proceedings. Within this area of research, the strong link between fast occurring neuroelectric signals and human sexuality could provide the neurobiological prerequisites to develop useful tools for the assessment or treatment of sexual preference disorders with particular forensic relevance.

The first study of this thesis provides a comprehensive overview and metanalytic aggregation of the research on neuroelectric correlates of human sexuality. The established substantial link between the two concepts was then used to develop an experimental design for a second study to test how neuroelectric methods can detect hidden sexual preferences. This second study used a known-group approach and focused on healthy and normal sexual preferences from the general population. Participants were instructed to hide their sexual orientation and results showed that neuroelectric signals were capable of detecting this concealment. There are, however, substantial limitations when such a method should be transferred to a forensic-psychiatric setting with a focus on the assessment of individuals. Also based on the summary of the literature, a third study was designed to test how neuroelectric stimulations of the brain could be utilized to induce changes in deviant sexual preferences (pedophilia). While results showed a reduction of attentional bias toward sexually preferred deviant content, this was not consistently observed throughout all the outcome measures and the effects were only sort-lived. This first attempt provides useful methodological implications for future work into a promising line of research with potential for treatment possibilities.

The three studies in the scope of this thesis have implications on the use of neuroscientific methods with practical utility for legal applications. Although such methods have already gained access into criminal proceedings, they should be seen as only one aspect among others to be considered in that context. The limitations of modern neuroscientific methods are matched by their promise to hold the key to the neurobiology of mental illness and our understanding of the brain in a forensic context.

ZUSAMMENFASSUNG

Neurowissenschaftliche Methoden haben signifikante Beiträge geleistet in der modernen Welt. In den vergangenen Jahrzehnten haben Forschungsarbeiten verdeutlicht, wie neurowissenschaftliche Erkenntnisse in der medizinischen Diagnostik angewendet werden; und diese Erkenntnisse haben auch die Rechtspraxis beeinflusst, wo das Zusammenspiel von Verstand, Gehirn und Verhalten immer mehr an Bedeutung gewinnt. Neben grundlegenden Fragen zum freien Willen oder zur Natur der Empathie, sind Vertreter der Forensischen Psychiatrie an praktisch nützlichen Anwendungen neurowissenschaftlicher Methoden im Rahmen der forensischen Beurteilung für strafrechtliche Prozesse interessiert. Innerhalb dieses Forschungsgebiets könnte ein starker Zusammenhang zwischen schnellen neuroelektrischen Signalen und menschlicher Sexualität die neurobiologischen Voraussetzungen für eine solche Anwendung erfüllen. Dieser enge Zusammenhang könnte umgesetzt werden zu einem methodischen Beitrag für die Entwicklung nützlicher Verfahren zur Beurteilung und Behandlung von sexuellen Präferenzstörungen mit besonderer forensischer Relevanz.

Die erste Studie dieser Arbeit bietet eine umfassende Übersicht und meta-analytische Synthese der Forschung an neuroelektrischen Korrelaten der menschlichen Sexualität. Die etablierte enge Verbindung zwischen den beiden Konzepten wurde genutzt, um ein experimentelles Design für die zweite Studie zu entwickeln, in welcher getestet wurde, inwiefern neuroelektrische Methoden dazu geeignet sind, verborgene sexuelle Präferenzen zu detektieren. In dieser zweiten Studie wurde die Methode der bekannten Gruppen verwendet, wobei anhand einer Stichprobe aus der Allgemeinbevölkerung auf normale Varianten gesunder Sexualität (Geschlechtspräferenz) fokussiert wurde. Versuchsteilnehmer wurden instruiert, ihre sexuelle Präferenz zu verbergen, und die Resultate haben gezeigt, dass neuroelektrische Signale eine solche Dissimulation aufdecken konnten. Allerdings ergeben sich substanzielle Einschränkungen, wenn eine solche Methode auf den forensischen Kontext mit dem Schwerpunkt auf Einzelfallbegutachtungen übertragen werden soll. Ebenfalls basierend auf der

Zusammenfassung der Literatur, wurde eine dritte Studie entworfen, um zu testen, inwiefern neuroelektrische Stimulationen des Gehirns genutzt werden können, um Veränderungen bei sexuellen Präferenzstörungen (Pädophilie) zu bewirken. Die Resultate zeigten zwar eine Reduktion der Aufmerksamkeitsauslenkung auf sexuell bevorzugte und deliktspezifische Bildinhalte; allerdings konnte dies nicht konsequent in allen abhängigen Variablen beobachtet werden. Zudem waren die Effekte nur von kurzer Dauer. Dieser erste Versuch bietet nützliche methodische Implikationen für künftige Arbeiten in einer vielversprechenden Forschungsrichtung mit potenziellen Behandlungsmöglichkeiten.

Die drei Studien dieser Arbeit haben Implikationen für den Gebrauch von neurowissenschaftlichen Methoden mit praktischem Nutzen in der Rechtsprechung. Obwohl entsprechende Methoden bereits Eingang in Strafverfahren gefunden haben, sollten sie in diesem Kontext lediglich als ein einzelner Aspekt unter vielen erachtet werden. Die Einschränkungen moderner neurowissenschaftlicher Methoden werden ausgeglichen durch ihr zukunftsträchtiges Potential, eine Schlüsselfunktion einzunehmen in unserem Verständnis der Neurobiologie psychischer Erkrankungen und des Gehirns im forensischen Kontext.

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LIST OF ABBREVIATIONS

DlPFC	dorsolateral prefrontal cortex
DSM-V	Diagnostic and Statistical Manual of Mental Disorders (5th edition)
EEG	electroencephalography
ERP	event related potential
fMRI	functional magnetic resonance imaging
GABA	gamma-aminobutyric acid
ICD-10	International Statistical Classification of Diseases (10th revision)
LPP	late positive potential
MRI	magnetic resonance imaging
PET	positron emission tomography
PD	Pedophilic Disorder
PSW	positive slow wave
QEEG	quantitative electroencephalography
RT	reaction time
SPECT	single photon emission computed tomography
tDCS	transcranial direct current stimulation

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1. Introduction

1.1 Clinical predictions in psychiatry

Mental health is a central issue for the well-being in humans. Social, economic and psychological burdens are immense (Beaglehole, Irwin, & Prentice, 2004). Major Depressive Disorder represents one of the leading causes of disability with accordingly high associated costs (Druss, Rosenheck, & Sledge, 2000; Greenberg & Stiglin, 2003). This impact on health emphasizes the necessity for effective treatment, specifically measures to guide decisions on diagnosis and therapy as well as therapy discontinuation. Psychiatric nosology focuses on symptoms. Extensive work has attempted to discover symptom-based predictors of e.g. relapse, for instance. Unfortunately, symptom-based markers (e.g., anxiety) may not be as useful for clinical predictions as assumed (Glue, Donovan, Kolluri, & Emir, 2010; Nelson, Portera, & Leon, 2005). Furthermore, methods to identify such symptoms are often based on subjective clinical parameters which show high variability (Hyman, 2007). Such methods and diagnostic tools (e.g.; DSM-5, American Psychiatric Association, 2013; ICD-10, World Health Organization, 1993) are also challenged by a high rate of comorbid cases and a divergence and variety of underlying etiologies of the psychiatric disorders. Therefore, the same treatment for different patients suffering from the same psychiatric disorder may be inappropriate (Linden, 2012).

The current tools in psychiatry to diagnose and guide treatment processes are based on phenomenological conceptualizations of diseases using lists of symptoms (Stephan & Mathys, 2014). It has been noted that these concepts represent categorizations with a primarily descriptive character and show limited predictive validity (Cuthbert & Insel, 2013). There has been a call for diagnostic tests that are suitable for predicting treatment response, discontinuation, or other clinical outcomes at the individual level (Kapur, Phillips, & Insel, 2012). The underlying and precise mechanisms for psychiatric illnesses that could simplify or clarify the divergence and variety with these disorders seem also far from understood. This critical view of psychiatric nosology neglects

its often complex development through centuries of clinical observations with constant adjustments (e.g. Kendler, 2020). Not only are classification systems in psychiatry based on a broad set of research in the respective field and expert consensus, they also provide the current diagnostic concepts utilised in daily practice with the possibility of progressive refinements (Jablensky, 2016). Proponents of the critical view of psychiatric nosology also emphasize the importance of neuroscientific methods for sufficient clinical accuracy at the subject-level (e.g. Zhang, Braun, Tost, H., & Bassett, 2020). However, introducing such neuroscientific methods in psychiatry is often difficult (e.g. Maples-Keller et al., 2020) and their utility in clinical practice is still reduced to diagnostic tests for the exclusion of more organic causes of brain diseases (Stephan & Mathys, 2014). This duality can also be illustrated in major depression with its particular relevance for clinicians.

On the patients side the current state of psychiatry and the lack of individually valid predictors to guide treatment can hinder optimal treatment decisions. Moreover, in reaching a decision on whether a patient suffers from a given psychiatric disorder or not, he or she will often be involved in the process (e.g., through clinical interview). Research has so far emphasized the importance of continuing antidepressant medication treatment after an episode of major depression has responded to treatment, showing that continuing treatment with antidepressants can prevent up to 70% of relapses (Geddes et al., 2003) while discontinuation may lead to rapid relapse - within three months in up to 40% (DeRubeis, Siegle, & Hollon, 2008; Hollon et al., 2005). Guidelines and clinicians therefore are advising long-term therapy. Lengthening the depressive state by delaying therapeutic success again reduces chance of remission (Altamura, Dell'osso, Vismara, & Mundo, 2008), increasing economic and individual costs (Malone, 2007; Simon, Khandker, Ichikawa, & Operskalski, 2006). This often leaves the decision to discontinue medication in an inadequate compromise between psychotherapy guidelines and patient's initiative. Up to 70% of patient's self-terminate antidepressant medication or psychotropic medication within a short period (Lee & Lee, 2011),

likely contributing to the high prevalence and relapse rates seen in depression. For mental illnesses in general nonadherence has been discussed as the leading cause of relapse (Barkhof, Meijer, de Sonneville, Linszen, & de Haan, 2012). Here the question would be how the inclusion of neuroscientific methods could potentially improve this treatment process. Basically, the suggested approaches require the acquisition of neurophysiological data from the depressive patient's brain and using that data to predict treatment response or relapse after discontinuation. While a number of studies have been conducted on this issue, summaries of the literature mostly highlight the potential of such approaches to depression (Enneking, Leehr, Dannlowski, & Redlich, 2020; Shapero et al., 2019) while not quantifying their benefit beyond the current routine clinical practices. When data is actually aggregated (meta-analysis) the predictive capabilities of neuroscientific data in depression have been called into question (Widge et al., 2019) while more needed research to improve their weaknesses (e.g. methodologic heterogeneity) is highlighted.

In sum, within the field of psychiatry the precise underlying causes and mechanisms for relevant mental disorders do not seem to be fully understood. This leads to a lack of individually valid predictors to guide treatment. These obstacles to optimal treatment processes can further lead to the necessity to shift responsibility to the patients themselves. Apart from a patient's involvement in the decision process, the relationship between clinician and patient can be an essential factor for clinical outcome in psychiatry (Priebe et al., 2011). However, in certain areas of psychiatry this involvement has to be more limited and is not compatible with aspects of security.

1.2 The case of forensic psychiatry

Criminality and mental disorders can be entirely disassociated from each other. In some instances, however, for people with a mental disorder who commit a crime, the care by forensic-

psychiatric services is favoured. Forensic psychiatry can be regarded as a subdivision of general psychiatry specialized for the treatment of the criminally insane. The exact point of transition from general to forensic psychiatry is not always clearly defined and can vary over time and place since statistical criteria for normality within a society can play a role (Hoff, 2006; Nedopil, 2009). Generally, a legal definition of insanity has to be met. This can be traced back to Roman law which stated restraint but not punishment for a mentally ill man killing his mother in an insane state (Spruit, 1998). Medieval discussions of insanity and its legal aspects date back to the 13th century (Gordon & Khosla, 2014). Whether a person committing a crime was in their right mind during the act was initially decided by judges and only in the first half of the nineteenth century did psychiatrist and psychologist start to play a more crucial role in this decision (Wetzell, 2009). Throughout history forensic psychiatry grew as a response to the awareness that offenders with mental disorders need special treatment. Potential dangerousness and risk to others would serve as a key factor for a patient to be treated by forensic services (Khosla, Davison, Gordon, & Joseph, 2014) with special regulations stated in the legal systems accordingly. Prisoners who pose serious challenges to prison medical services are sometimes also treated in secure forensic-psychiatric hospitals.

Patient antisocial behaviour can be seen as the main component distinguishing forensic psychiatry from general psychiatry. Forensic patients are not only psychiatric patients but also offenders. They frequently suffer from severe mental disorders, often with psychotic symptomatology (Andreasson et al., 2014; Degl' Innocenti et al., 2014). A high rate of comorbid substance abuse problems, developmental issues, and personality disorders is also common (Degl' Innocenti et al., 2014). Past violent behavior was recorded for a large proportion of this patient group (Goethals, Vorstenbosch, & Vanmarle, 2008), with aggressive behavior as an important reason for referral to forensic institutions (Smith & Humpreys, 1997). Forensic patients are frequently marginalized with unemployment and lack of education and therefore also coupled with higher stigmatization (West, Yanos, & Mulay, 2014). These patient

characteristics pose further problems for practical clinical work. In contrast to general psychiatry forensic patients can be less motivated to engage in treatment (Mulder, Jochems, & Kortrijk, 2014).

Legally mandated treatment is not necessarily ineffective (Hachtel, Vogel, & Huber, 2019). Caring and authoritative approaches can be beneficial to therapeutic outcome. Involuntary admission and a lack of insight into one's own disorder can, however, still impede the basic need for compliance in a therapeutic setting (Ghaemi & Pope, 1994). This is associated with a challenge of the basic notion of a patient as the person receiving treatment because of a form of suffering. With forensic patients it is often rather their environment or society at large that may suffer due to the patients' actions whereas the patients themselves do not necessarily experience adversity because of their medical condition. Therefore, success and efficiency of forensic psychiatry are linked to the protection of society apart from improving a patient's wellbeing. This triangular relationship between clinician, patient, and society can pose ethical and moral conflicts making the requirement of solid ethical principles within the field of forensic psychiatry essential (Niveau & Welle, 2018). Although a specific subspecialty within psychiatry, forensic psychiatry can be seen as a highly challenging and important field in health care. This relevance is reflected by the comparatively high portions of the mental health budget allocated to by forensic psychiatry despite its comparably small patient population (Fazel, Fimińska, Cocks, & Coid, 2016).

Despite the importance of the forensic psychiatry stated above, similar to general psychiatry (cf., Chapter 1.1) there are challenges for assessment, the prediction of treatment response, and relapse after treatment. Although it remains a legal issue, whether a particular diagnosis has relevance within a juridical case, it is still up to the clinicians involved to properly outline the diagnosis itself (Greenberg, Shuman, & Meyer, 2004). Aspects specific to forensic psychiatry outlined above can pose even more severe challenges within this task. Apart from the fact that patient compliance in treatment may be less pronounced than in general psychiatry,

in certain cases forensic patients will have an interest to hide information in self-reports. Systematic reviews point towards multiple knowledge gaps within crucial domains in the field of forensic psychiatry (e.g. diagnostic and risk assessments, pharmacological treatment, psychological interventions) (Howner et al., 2018). Conducting studies within a forensic setting can also be associated with more difficulties when accessibility to study samples is strictly limited. A lack of data in assessing expert performance has been pointed out as well (Dror & Murrie, 2017). While some studies support an accurate prediction of imminent violent behavior (Ramesh & College, 2018) problems have been highlighted when it comes to general divisions of violent and non-violent groups (Mossman, 2011). Clinicians could be biased to overestimate occurrence of violent behavior since they can be liable for the harmful behavior of their patients (Kermani & Drob, 1987). Further problems are severe stigmatizations alongside the diagnosis of forensic relevant mental disorders or legal consequences as a result of misdiagnosis. A combination of these problems has been recently illustrated in the example of pedophilia (Mokros, Habermeyer, & Küchenhoff, 2018) with its particular forensic relevance.

Attempts were made at improving diagnostic methods for this disorder. Apart from a screening scale (Seto, Stephens, Lalumière, & Cantor, 2017), phallometric methods have also been suggested (Freund, & Watson, 1991). Phallometric methods are frequently used and considered as valid. However, a lack of standardization has been noted (Murphy, Curry, Klapilová, Dwyer, Zikánová, & Fedoroff, 2019). These methods also require responsive subjects and are prone to distraction techniques (Renaud et al., 2009). Furthermore, phallometry requires invasive procedures not compatible with preservation of human dignity while some men only produce small penile or phallometric responses (Seto, 2009). In recent years visual tasks relying on implicit measures have been researched in this regard as well. In some instances these measures were combined with eye-tracking (Fromberger et al., 2012; Nemetschek, 2013) or event-related brain potentials (ERP) (Knott, Impey, Fisher, Delpero, & Fedoroff, 2016). ERP are calculated from recordings with electroencephalography (EEG) and allow for a very high

time resolution. Moreover, the use of ERP for inferences about cognitive processes prior to conscious awareness has been suggested (Libet, 1985, 1999). Therefore, neuroelectric signals measured on the scalp could have implications for diagnostic tools in forensic psychiatry, specifically the assessment and treatment of sexual preference disorders such as pedophilia.

There are further problems when it comes to treatment of such disorders, specifically pedophilia. According to recent reviews (Dennis et al., 2012; Khan et al., 2015) both pharmacological and psychological treatments have not shown long term reduction in pedophilic sexual arousal. This was also shown for pedophilic men who do not commit criminal offences (Mokros & Banse, 2019). Often psychotherapy is used and cognitive behavior-oriented methods are utilized (e.g. Fromberger, Jordan, & Müller, 2013). The goal here is the prevention of sexual assaults on children and not a change in podophile interest. Motivation and willingness to participate is an important factor for therapeutic outcome. Paradigms with a focus on behavioral conditioning show only small effects in the short term. Medication therapy could provide longer-lasting effects, but shows less participation due to the side effects of the medication (e.g. Hughes, 2007) such as libido reduction and erection failures. Recent approaches have investigated how non-invasive transcranial direct current stimulation (tDCS) can have an effect in a variety of psychiatric disorders by increasing inhibitory control (Kekic, Boysen, Campbell, & Schmidt, 2016). Using tDCS as a method to increase inhibitory control could also have implications in for the treatment of sexual offenders.

1.3 Biomarkers in forensic psychiatry

There have been numerous attempts at identifying biological correlates that could potentially be related to criminal behavior. This can be traced back to attempts at measuring arm lengths and their relation to criminality (Lombroso-Ferrero, 1911). In recent years there has been an increase in neuroscientific research and its potential applications to the law. This field, also called *neurolaw* (Shen & Gromet, 2015), deals with how brain science can have an

impact in legal and political matters with human cognitive neuroscience playing a pivotal role in countless issues within this field. A variety of potential applications of brain science to law are being explored. While fundamental issues such as e.g. free will (Sapolsky, 2004) are researched with neuroscientific experiments, within forensic psychiatry the admissibility of neuroscientific evidence in court proceedings is of practical relevance. In this regard, neuroscientific evidence has been submitted to support a lack of criminal intent (Wagner, 2010) and capability to support an insanity defence has been discussed as well (Jones, Schall, & Shen, 2014; Scarpazza, Ferracuti, Miolla, & Sartori, 2018; Scarpazza, Pellegrini, Pietrini, & Sartori, 2018).

Most commonly used methods in this regard are EEG, functional magnetic resonance imaging (fMRI), positron emission tomography (PET) and single photon emission computed tomography (SPECT). When these terms are used to search the official collection of published leading court decisions from the Swiss Federal Supreme Court[1] further cases can be found. Excluding two cases where financial responsibility for the acquisition of an MRI setting was debated 17 cases were identified in which neuroscientific methods were mentioned in court decisions. Table 1 lists these decisions and their content. Not all cases focus on the brain and in many cases methods were used when insurance benefits were debated with one decision referencing a study (Quack et al., 2007). Although in some instances these methods have been used to make inferences about mental states and draw legal consequences, neuroscientific methods alone are rarely stated as the defining factor in the legal documents. Additionally, no decision could be identified in which such methods were referenced in terms of routine forensic assessment[2].

[1] https://www.bger.ch/ext/eurospider/live/de/php/clir/http/index.php?lang=de was used to search for decisions from 1954-present
http://www.servat.unibe.ch/dfr/dfr_bge0s.html was used to search for decisions prior to 1954

[2] The search focused on the supreme court as the highest instance in the swiss judicial system publishing leading decisions for lower instances and courts. Discussions about using neuroscientific methods as forensic assessment can be found in decisions from other courts in Switzerland (e.g. fMRI as lie detection in case UG070045-O/U/br in Zurich).

Methods mentioned in Table 1 need to be scientifically recognized to be suitable for admission in courts. This recognition has to be achieved on a broad basis amongst researchers and practitioners within the medical sciences. It can be challenging to achieve this status when nonphysical mental states have to be described empirically. Furthermore, forensic assessments are most relevant in criminal proceedings in which also a higher burden of proof is required for a conviction compared to civil suits or trials. Most scholars would prioritize the minimisation of wrongful convictions over the minimisation wrongful acquittals (Nicita & Rizzolli, 2014) while the exact ratio is still debated (Posner, 1998; Volokh, 1997). Therefore, the highest demands should be carefully made for neuroscientific forensic assessments and their admission in criminal trials. In this regard, EEG evidence has already been reported as an important factor on two juror's decisions not to execute a defendant in the United States (Jones, Marois, Farah, & Greely, 2015).

Table 1

Published decisions of the Swiss Federal Supreme Court that mention neuroscientific methods

Decision	Year	Subject area	Methods	Purpose
100 V 104	1974	Social insurance law	EEG	Covering costs of EEG tests
104 Ib 179	1978	Administrative and public international law	EEG	Determine fitness to drive for an epileptic patient
117 V 369	1991	Social insurance law	MRI, EEG	Differentiation between commotio and contusio cerebri is discussed
117 V 359	1991	Social insurance law	EEG	Causality between accident and physical or mental problems
122 V 113	1996	Social insurance law	MRI, EEG	Exclusion of organic causes for visual problems
125 V 278	1999	Social insurance law	MRI	Diagnosis of brain atrophy
128 V 169	2002	Social insurance law	MRI	Diagnosis of brainstem glioma
129 II 353	2003	Administrative and public international law	EEG	Diagnosis of epilepsy
130 V 396	2004	Social insurance law	MRI	Diagnosis of problems in the spinal column
133 V 450	2007	Social insurance law	EEG	Diagnosis of epilepsy
134 V 109	2008	Social insurance law	fMRI, SPECT	Causality between accident and physical or mental problems
134 V 231	2008	Social insurance law	MRI, fMRI, SPECT, PET	Causality between accident and physical or mental problems
137 IV 219	2011	Criminal law and penal system	MRI	Accident caused by an MRI
137 V 167	2011	Social insurance law	EEG	Covering costs of EEG tests
140 V 193	2014	Social insurance law	MRI	Study on MRI as tests for mobility is referenced
141 V 405	2015	Social insurance law	MRI	Diagnosis of problems in the spinal column
143 V 124	2017	Social insurance law	MRI	Diagnosis of problems in the spinal column

Note. Decision: The first number refers to the year since the court's jurisdiction was established (1875 was the first year), the roman numeral refers to the subject area and the last number refers to the page.

In the case described by Jones et al. (2015) EEG recordings were used to argue for the defendant's inability to understand the consequences of his actions. The popularity, recent rise (e.g. Beech, Carter, Mann, & Rotshtein, 2018), and the visualisation capabilities of

neuroscientific methods should not be abused or overstated when presented as evidence. Methodological details would be more important. A thorough search for the published scientific literature may in some instances already allow answering the question whether a certain neuroscientific method is adequate and precise enough to be admitted to court according to the scientific community. With regards to EEG there is an advantage in its high time resolution. Although the exact translation from EEG signals to mental states is not fully understood several studies have been conducted on EEG recordings in relation to sexuality and its representation in the human brain. The question is whether this line of research has meaningful implications for the use of ERP as a tool for assessing hidden sexual preferences in forensic psychiatry. Interestingly, EEG signals can also be targeted and manipulated using tDCS. Research has shown how the dorsolateral prefrontal cortex (dlPFC) is involved in pedophiles when child related pictures are attended to (Poeppl et al., 2013). Anodal tDCS targeted at the dlPFC of podophilic patients could have implications for possible treatment capabilities.

1.4 Neuroelectric correlates of forensically relevant sexual behavior

1.4.1 Methodological basics

Electrical activity of the human brain can be recorded with electrodes placed on the scalp. Nerve cell potentials spread passively through the brain, the skull, and cerebrospinal fluids. Electrodes that are placed on the scalp measure electric voltage that is assumed to originate from postsynaptic potentials of pyramidal cells (Luck, 2014). The signals are less related to the more commonly known action potentials.

Pyramidal cells in the cortex are perpendicularly oriented to the scalp and ordered (Luck, 2014). Unordered cell structures where fluid particles do not follow smooth paths in layers result in electrical activity that will be cancelled out and not be measurable on the scalp (Luck, 2014). Therefore, electrical signals from the basal ganglia, for instance, are hard to measure with EEG (Luck, 2014). The recorded potentials are generated by neurotransmitters binding to

postsynaptic receptors leading to a depolarization. Neurotransmission between cortical pyramidal cells is achieved through the release of neurotransmitters in the synaptic cleft resulting in an excitation or inhibition of the target neuron (Im, 2018). While dopamine, serotonin and acetylcholine are assumed to have a regulatory role in this transmission, glutamate and gamma-aminobutyric acid (GABA) are the main factors driving inhibitory or excitatory postsynaptic potentials (Kandel, Schwartz, & Jessell, 2000). This results in a shift of electrical charges along the cell membrane.

Consequently, positively and negatively charged sides of a pyramidal cell can create a dipole and thousand similarly oriented dipoles like this create a measurable amount of voltage on the scalp, resulting in the recorded EEG signal (Michel, Koenig, Brandeis, Gianotti, & Wackermann, 2009). This implies that only certain parts of the human brain are possible generators of EEG signals and that signals recorded at a specific scalp electrode (e.g., at the temporal site) cannot necessarily be attributed to a temporal neural generator directly beneath that particular electrode. Consequently, EEG signals have a high time resolution and a low spatial resolution. In modern neuroscientific experiments EEG activity is often related to an event of interest (Luck, 2014). Usually, on-going EEG activity is recorded while an event of interest (e.g., the presentation of an emotional picture) is induced experimentally. The segments from the on-going EEG activity where the event of interest occurred (event-related) are averaged and this signal is referred to as ERP (Luck, 2014). The exact relationship between a mental state related to an event as inferred from ERP and the processes in the human brain at the cellular level is not clearly understood. This makes ERPs difficult to interpret.

Since EEG signals result from electrochemical processes within the brain, neuroscientific methods to target and modulate such signals by influencing electrocortical activity have also been developed. In principle, such methods usually involve induced electrical or magnetic activity with the goal to modulate the electrochemical processes at the cellular level within the brain. Just as EEG can be recorded invasively within the brain (e.g., Nager et al.,

2011) cortical stimulations can also be induced invasively (e.g., Visser-Vandewalle et al., 2005). While both methods show a historical origin in invasive intracortical experiments, modern attempts at neuromodulation focus on non-invasive and painless means.

Motor-evoked potentials have been produced through electrical pulses using a pair of surface electrodes (Merton & Morton, 1980). Modern tDCS can be used to noninvasively apply weak direct currents over the skull (Dymond, Coger, & Serafetinides, 1975). Using anodal tDCS membrane potentials of selected brain regions can be changed influencing their excitability (Stagg & Nitsche, 2011). The result is a focal, short lasting (20 min) reversible change in excitability, with only minor side effects (e.g., dizziness). While anodal tDCS increases excitability cathodal tDCS decreases it and even long-term synaptic changes facilitating neuroplasticity and excitability have been suggested (Priori, 2003). These induced changes can also be observed through EEG recordings (Mangia, Pirini, & Cappello, 2014; Roy, Baxter, & He, 2014) and their utility in the treatment of psychiatric disorders has also been researched (Meron, Hedger, Garner, & Baldwin, 2015).

1.4.2 Implications for forensic psychiatry

Neuroelectric correlates have also been targeted in studies focusing on forensic psychiatric topics. One line of research has used EEG methods to investigate general impulse control (e.g. Maurer et al., 2016). Here, decreased ERP amplitudes during inhibitory control related to the frontal lobe were repeatedly linked to inhibitory deficits (Chen, Tien, Juan, Tzeng, & Hung, 2005; Munro et al., 2007; Vilà-Balló, Hdez-Lafuente, Rostan, Cunillera, & Rodriguez-Fornells, 2014). Similarly, in subjects with high levels of psychopathic traits, reduced ERP amplitudes have been recorded during the viewing of pictures related to pain (Cheng, Hung, & Decety, 2012; Decety, Lewis, & Cowell, 2015). Higher scores on meanness traits were also associated with reduced ERP amplitudes during the viewing of victims in scenes of aggression (van Dongen, Brazil, van der Veen, & Franken, 2018). Different ERP amplitudes during the

processing of rewards have also been described for individuals with higher and lower scores of psychopathic traits (e.g. Salim, van der Veen, van Dongen, & Franken, 2015). When compared to healthy controls psychopathic and antisocial subjects also showed reduced ERP during error-related feedback (Brazil et al., 2009, 2012).

Regarding sexually deviant behavior, reduced ERP amplitudes during an oddball task have been linked to an onset of sexual behavior at a such an early age that it could be considered as deviant (Iacono, Malone, & McGue, 2003; Iacono & McGue, 2006). ERP have also been used in studies to differentiate sexual deviance from samples with normal sexual preferences by using visual stimuli matching the respective sexual desires. Pedophilic patients showed less pronounced ERP amplitudes when normal adult sexual content is displayed in pictures (Knott et al., 2016) and paraphilic individuals in general had more pronounced ERP amplitudes when faced with paraphilic content (Waismann, Fenwick, Wilson, Hewett, & Lumsden, 2003) compared to healthy controls. These amplitude measures were also correlated with self-reports on sexual abuse or sexual preferences in the sexually deviant samples (Knott et al., 2016; Weismann et al., 2003). Comprehensive reviews and statements on the clinical precision of such measurements are, however, lacking and it is hard to estimate whether such measures satisfy standards for practical utility in forensic psychiatric assessments. ERP could have implications as diagnostic tools for hidden or supressed sexually deviant preferences but so far no experimental work has tested whether hidden sexual preferences can be observed using ERP.

Neuromodulation with tDCS, for instance, has already been discussed as a tool to enhance or improve general moral reasoning and behavior (Conan, 2019) and it's potential to improve empathy or reduce violent behavior is also being reviewed (Sergiou, Santarnecchi, Franken, & Van Dongen, 2019). By inhibiting cortical excitability tDCS has also been used to establish a relationship between deceptive behavior and cortical activity (Luber, Fisher, Appelbaum, Ploesser, & Lisanby, 2009). Using tDCS deceptive behavior was facilitated while a decrease in feelings of guilt was observed presumably through a reduction of moral conflict

(Karim et al., 2010). Other studies showed how tDCS can also be used to interfere with deceptive responses (Priori et al., 2008). Such modulations were observed in different deceptive contexts with different response modalities (Fecteau et al., 2013). The modulation of deceptive responses was mostly shown when general information was given through a deceptive response while deception with regards to personal information was less influenced (Mameli et al., 2010).

There appears to be a predominant focus on researching deceptive behavior with tDCS and a lack of tDCS studies on the modulation of deviant or dysfunctional sexual behavior (Sauvaget et al., 2015). In one case tDCS was used in combination with medication and successfully reduced sexually disinhibited behavior in a case of acute mania (Schestatsky et al., 2013). More influences on sexual experience and behavior through neuromodulation have been reported as side effects in mostly non-forensic cases but using invasive stimulation (e.g. Portenoy et al., 1986; Visser-Vandewalle et al., 2005). Again, there is a lack of comprehensive reviews and it remains unclear on how neuromodulation through tDCS could have a practical utility for the treatment of sexual deviance in forensic samples.

In summary, while both ERP and tDCS could have potential as tools for forensic-psychiatric assessments of sexual deviance, there is a lack of overarching reviews on the matter in the literature. The experimental designs necessary to outline their methodological potential in this regard have not been suggested in the scientific community. If the human brain shows very specific neuroelectric correlates for sexual properties, this could be a very promising and neglected line of research for forensic assessments and treatment possibilities. In the narrow sense, a systematic review of the literature is needed to evaluate the potential of neuroelectric correlates to describe hidden sexual orientations and modulate deviant sexual preferences. Through this evaluation more detailed experimental designs can be proposed and implemented in empirical tests.

2. The Present Thesis

2.1 Aims and research questions

The aim of this dissertation was to increase the understanding of neuroelectric processes related to sexuality in the human brain and evaluate the forensic potential of such processes. In the first study presented in this thesis the aim was to summarize and evaluate the state of the research on neuroelectric correlates of human sexuality. Reviews on this topic are lacking. A systematic review combined with meta-analytic integration could evaluate the potential of such methods for sexual disorders in forensic psychiatry as well as provide a first comprehensive overview on the subject. Thus, the following first research question was derived:

RQ 1: *Is there a significant association between neuroelectric components and sexual processing in the human brain that could have potential utility in forensic psychiatry?*

Based on the summary of the literature the relevant methodological aspects can be chosen to empirically test whether and how sexual preferences can be hidden, supressed or pretended when they are measured through neuroelectric methods in the human brain. The long-term goal would be to make inferences on forensically relevant cases. In this thesis, however, more easily accessible samples from the general population without clinical or forensic relevance will be used as known groups. This allows for a broader perspective, and quantifications on how a neuroelectric test can discriminate between general groups of individuals already known to have a particular sexual preference and groups who do not have certain preference. Such known group approaches are often used to support construct validity (e.g. Bolarinwa, 2015; Wygant, Ben-Porath, Arbisi, Berry, Freeman, & Heilbronner, 2009). The following second research question was derived:

RQ 2.1: *Can human sexual preferences be faked or suppressed from neuroelectric recordings?*

Using healthy samples from the general population also allows for assumptions about more general aspects of sexuality to be tested that are not reduced to clinical or forensic samples. Without presumed cognitive impairments (Shumlich, Reid, Hancock, & Hoaken, 2019) or ongoing pharmacological treatments (Winder et al., 2019) neuroelectric measurements can be used to describe the temporal details of hidden sexual preferences in general with implications about different stages of observability. Thus, the third research question was derived:

RQ 2.2: *Are there different processing stages in the human brain where hidden sexual preferences manifest themselves differently when recorded with neuroelectric methods?*

Based on the summary of the literature the relevant methodological aspects can be chosen to empirically test whether and how forensically relevant sexual preferences could be modulated using neuroelectric stimulation. There is a need for therapeutic methods showing effective treatment in forensic contexts with patients suffering from sexual preference disorders. Methods for neuroelectric modulation could provide a potential non-invasive option, but this has not been empirically tested within a controlled experiment involving forensic-psychiatric patients. The following research question was derived:

RQ 3: *Can pedophilic sexual preferences be modulated using neuroelectric stimulation?*

2.2 Summary of Study 1

Neuroelectric Correlates of Human Sexuality: A Review and Meta-Analysis

Background: Although neurotransmission in the brain is mainly performed through electrochemical signals, there are no systematic reviews of the neuroelectric correlates of sexual arousal in the human brain. Sexual processes influence human cognition subliminally, in a matter of milliseconds and at the earliest processing stages. Electrophysiological methods can capture such processes in the human brain with high temporal resolution. A first extensive overview of the literature could identify possible limitations within the field while highlighting methodological directions for future research.

Method: Using a formula with the identified technical terms as key words, a systematic search was conducted in PubMed, PsycINFO, PSYNDEX, PsycARTICLES, Google Scholar, Scopus, and Web of Science. English, German, French, Italian, Portuguese, Russian, and Chinese studies were included in the results. Data was aggregated through meta-analysis. A random-effects model was chosen, and studies were weighted using the DerSimonian–Laird method.

Results: A total of 255 reported studies covering 81 years of research (1936-2017) were identified. The results indicated significant effect sizes for specific neuroelectric brain potentials during sexual stimulation (P3: Cohen's $d = 1.82$, $N = 300$, LPP: Cohen's $d = 2.30$, $N = 510$) with high heterogeneity between the combined studies. Using neuroelectric signals, past studies repeatedly differentiated sexual processing from other emotional states since such signals take on their most pronounced form in sexual contexts. Studies have also manipulated neuroelectric correlates related to sexuality by using non-invasive techniques for neuromodulation. Human sexuality appears to be different from other emotional processes and

this specificity is also present in its neuroelectric correlates. Cognitive attention could be linked to this specificity which might also be observable during early preconscious processes.

Conclusion: Although research in this field suffers from a high methodological heterogeneity common trends have shown that human sexuality is presumably more strongly linked to electric activity in the brain than other emotional states. This relationship could be further explored to design a neuroelectric test with the potential to detect hidden sexual preferences or to empirically test the utility of non-invasive neuroelectric manipulation for the treatment of sexual preference disorders. While such experiments are still lacking, neuroelectric correlates are already used for evaluations of an individual's legal responsibility for certain sexual offenses.

2.3 Summary of Study 2

Automaticity of Early Sexual Attention: An Event-Related-Potential Study

Background: Research on forensic assessment of sexual deviant interest is struggling with finding measures with clinical utility at the subject level. A promising line of research focuses on measures of visual attention in which sexual stimuli are used as distractors. These approaches are based on the assumption that initial automatic and preconscious cognitive processes are involved when sexually relevant stimuli are encountered. If sexual attention is guided by initial automaticity, task-irrelevant sexual distractors should slow down performance in attentional tasks. While most research on this topic used behavioral measures the present study combined event-related potentials (ERP) with behavioral measures to investigate cognitive processes prior to motoric executions. Neuroelectric signals have been shown as a promising tool to study human sexual attention.

Method: 40 hetero- and 40 homosexual men participated in the study. Within each group, half of the participants were instructed to hide their sexual orientation. Attentional tasks involved

the location of dots on the screen either during or after the presentation of sexual images (nude or clothed men and women) as distractors. Event-related brain potentials (ERPs) and behavioral responses in terms of reaction times (RTs) were recorded during the experiment.

Results: The results show how despite pretending otherwise, a match between sexual orientation and sexual distractor can influence cognition as inferred from ERP at early processing stages where motoric execution is not yet possible (250-500 ms). Pretending indifference to a sexual distractor influenced RT mostly at the latest processing stage (after 500 ms) when conscious motoric movement was also possible. The effect of stimulus explicitness (nudity of the sexual content) was, however, the most pronounced one throughout all processing stages starting at the earliest (150-200 ms). This effect appeared to influence ERP both earlier and more strongly than stimulus gender.

Conclusion: When a sexual preference is actively supressed, it can still be observed through neuroelectric signals before conscious motoric movement is possible. Gender preference, however, seems to affect neuroelectric signals at a later stage and less pronounced than the explicitness of a stimulus regardless of gender. Encoding sexual characteristics depending on gender could be driven by automatic attention and the associated neuroelectric correlates can be measured but there are problems when such measurements should be transferred from a laboratory setting to a forensic assessment of age preference with legal consequences.

2.4 Summary of Study 3

The Effects of Acute Transcranial Direct Current Stimulation on Attentional Bias in Pedophilic Disorder: A Pre-registered Pilot Study

Introduction: Individuals with Pedophilic Disorder (PD) experience personal and interpersonal difficulties and are at risk of sexually offending against children. Recent studies have indicated that sex offenders with child victims with PD display an automatic attention bias for child-

related stimuli as well as reduced activity in the dorsolateral prefrontal cortex (dlPFC), a brain area involved in cognitive control, including control over sexual arousal. Neuroelectric modulation of the dlPFC using transcranial direct current stimulation (tDCS) could reduce the putative pedophilic attention bias and provide a therapeutic aid.

Method: A single 20-minute session of active anodal vs. sham tDCS over the left dlPFC to 16 PD patients with child victims and 16 matched healthy controls was used, while they performed a task requiring controlled attention to computer-generated images of clothed and nude children and adults. During the attentional tasks reaction times and eye movement were recorded.

Results: An automatic pedophilic bias across multiple outcome measures was observed in patients and a reduction in this bias was shown during active vs. sham tDCS but only in some outcome measures. This effect only lasted for about 20 min during a session. Controls did not display the expected bias for adult vs. child images, possibly due to the salience of child images capturing their attention in unintended ways.

Conclusion: The findings need to be considered within the methodological problems specific to tDCS studies and the clinical sample used. Self-reports showed that blinding was not ensured since participants were able to differentiate active from sham tDCS. Mental health conditions such as comorbid depression and anxiety were not excluded in the already difficult to access patient group. In this first attempt potential methodological improvements were identified to assist future research. The modest yet encouraging preliminary results show that non-invasive neuroelectric stimulation could provide a promising therapeutic aid for PD that is worth investigating further.

3. Discussion

3.1 Neuroelectric correlates and their implications

RQ 1 revolved around the association between human sexuality and its neuroelectric correlates in the human brain. The first study identified the relationship between human sexuality and neuroelectric correlates as well as its potential for the use in forensic psychiatry. This also served as a first comprehensive overview of the literature for future studies since systematic reviews or meta-analytic work was surprisingly lacking in this field. Addressing RQ 1, intriguing findings became apparent in the first study. Throughout over 60 years of research it was shown how first invasive neuroelectric open-brain studies, also addressing states of sexual arousal (e.g. Penfield & Rasmussen, 1950), described how the mapping of the genitals might not be in line with the presumed somatotopic continuity. An abnormally high degree of synchronous widespread electric activity in the human brain comparable to seizures has further been assumed for orgasms. Later several typical neuroscientific EEG experiments also showed how sexual stimuli often lead to most pronounced signals when compared to many other emotional states (only sometimes rivalled by signals induced through gruesome content such as mutilations). Although not yet fully understood, the specificity of human sexual arousal could be linked to its likewise unique neuroelectric properties. Apart from forensic psychiatry, neuroelectric signals associated with sexual arousal could also provide a useful research tool to study how mental states map onto brain states, a process that has been regarded as a primary research goal to establish the value of neurophysiological methods in general psychiatry (Stephan et al., 2016).

Apart from these findings some intriguing restrictions also became apparent when addressing RQ 1. The highest number of studies on the subject were conventional EEG experiments with their typical problems. The consistently small samples, the lack of preregistered studies, and the lack of a single replication study as well as potential publication bias make it hard to derive meaningful conclusions within the field. In addition, the lack of

reported statistical effect sizes (only 25 out of 127 studies), the high methodological heterogeneity overall and also within the small number of studies used for meta-analysis might put the interesting implications of the first study into question. An implicit assumption based on the first study was that especially neuroelectric methods could have the potential to detect hidden sexual preferences in the human brain. Alternatively, this could be an overinterpretation of a largely inconclusive research field with only highly heterogeneous data available.

Nevertheless, addressing RQ 2.1 and RQ 2.2 the second study was designed to bypass many methodological limitations encountered in the literature. When operationalizing visual sexual stimulation to achieve a neuroelectric effect, attempts were made to control for basic physical properties between the sexual stimuli and non-sexual images used for comparison. Furthermore, other emotional dimensions such as emotional valence and emotional arousal (when rating the visual stimuli) were controlled so that any effects of the sexual stimuli on EEG could be attributed only to an ascribed sexual attractiveness to the stimuli. Data on sexual orientation was also collected for controlling. Taken together Study 2 represents a highly controlled laboratory experiment with preregistered hypotheses and corresponding low external validity. With regard to RQ 2.1 the results show how sexual preference can more easily be hidden from mandatory motoric execution in terms of a performance measure (as inferred from RT) compared to earlier cognitive processes inferred from ERP. While only suggestive till further replication these results hint at a difficulty for the human brain to supress a sexual preference from neuroelectric detection at 250-500 ms (positive slow wave; PSW) after stimulus presentation. Further research into this area should apply experimental designs that specifically target this time window. Considering RQ 2.2 there was an unexpected and predominant effect of stimulus nudity/explicitness throughout all the time windows and cognitive processing stages observed. Encoding sexual relevance from obvious nudity could take priority over the encoding of gender characteristics in the human brain. This could lead to

a quicker recruitment of neuroelectric resources and it might be accomplished faster and with less mental effort compared to gender categorization.

In sum, Study 2 supports the notion that hidden sexual preferences could be detected with ERP, but the experimental setting lacks in transferability to a forensic context. It is unclear as to what results would look like when age preference was studied instead of gender preference. EEG signals are also highly influenced by situational context with countless variables such as time of day and seasonal variability affecting the recordings (e.g. Peterson & Harmon-Jones, 2009). The higher burden of proof in criminal proceedings mentioned above (sometimes discussed to be above 95%; Weinstein & Dewsbury, 2007) in which forensic assessments could also play a role, has set a very high standard for single-subject evaluations based on EEG data. This is a problem that cannot be addressed by a single study but only by more rigorous standardization of methodology across studies ensuring comparability and aggregation of evidence. As seen in Study 1 this still remains a problem within the field.

Similarly, based on Study 1 assumptions were also made about the capabilities to neuroelectrically modulate sexual interest in forensic psychiatric contexts. In this regard, there were far less studies available compared to the neuroelectric recordings considered for Study 2. Thus, Study 3 was a first attempt at such an endeavour. Study 3 was designed as an experiment to evaluate the modulation of pedophilic sexual interests using tDCS on the dlPFC (preliminary results of this study have been presented elsewhere Pezzoli et al., 2018). While only short-lasting effects were observed on only a subset of outcome measures Study 3 highlighted first methodological issues for a promising line of research. With regard to RQ 3 initial empirical data showed that at least short-lived modulations of attentional bias could be observed in pedophilic patients. Although this is by no means a sign of successful treatment of pedophilic interest, it could be interpreted as a first step in that direction. The lack of side-effects and invasive means when using tDCS could also render this method as more preferable for patients compared to pharmacology. Instead of focusing on the spatially broadly defined

dlPFC, a brain region involved in many cognitive functions, future attempts should be made to localize (fMRI) relevant brain areas as targets on a subject-level.

3.2 General Discussion

The general results of this dissertation show how neuroelectric correlates of human sexuality have been searched extensively, yet with a clear lack of focus on forensically relevant topics. The general characteristics of ERP and to a lesser extent quantitative EEG methods (QEEG) would seem advantageous to infer about hidden mental states. Looking at general EEG research on human sexuality, methodological reproducibility and transparency is still lacking. However, more rigid standards and recommendations for reviewers are on the rise (Keil et al., 2014; Luck & Gaspelin, 2017). Using evaluations on large sets of data even detailed instructions on how to compute specific components are being published (e.g. frontal alpha asymmetry; Smith, Reznik, Stewart, & Allen, 2017). Methodological solutions to old problems (e.g. corrections for multiple comparisons) have also been addressed in recent years (Groppe, Urbach, & Kutas, 2011a, 2011b) and sophisticated solutions based on machine learning are incorporated into freely available toolboxes (Winkler, Haufe, & Tangermann, 2011). In combination with more general publication strategies such as processes of preregistration, data sharing, or accepting publications based on study designs regardless of results, this research could go into a favourable direction in terms of reproducibility.

One reason for the lack of studies on forensically relevant samples in this line of research is the limited accessibility of suitable samples of participants. Other problems could lie in the purpose of accessing hidden thoughts against an individual's will. Such endeavours are associated with lie detection which has been discussed controversially since the 1920s (Grubin & Madsen, 2000). Part of the controversy can be ascribed to the notion of a methodically flawed test threatening individual liberty. However, different applications have also been discussed. For convicted sex offenders, potential benefits during treatment and supervision was mentioned

(Abrams & Simmons, 2000). In such a setting methods for lie detection could be used to overcome denial or identify treatment need (Grubin, Kamenskov, Dwyer, & Stephenson, 2019; Grubin, Madsen, Parsons, Sosnowski, & Warberg, 2004).

Another trend that can be observed in the literature was the movement from focusing on anatomical structures and emphasising the importance of the dynamics in the brain within a sexual context. Studies have even shown how neuroelectric correlates of sexual arousal can be experimentally targeted and influenced (Ferrari, Lega, Tamietto, Nadal, & Cattaneo, 2015; Prause, Siegle, Deblieck, Wu, & Iacoboni, 2016). A sexual context (e.g., through visual images) is usually necessary for such an endeavour. Although such visual imagery might cause some distress for the participants or pedophilic patients, studies have demonstrated that pedophilic participants are willing to participate in scientific work focusing on treatment options if confidentiality is not at risk and there is no moral judgement (Beier et al., 2009; Cantor & McPhail, 2016).

The experimental work further showed how neuroelectric correlates of sexual processing can usually be differentiated from other emotional states. This was shown throughout a heterogenous group of studies found in Study 1 and replicated in Study 2 with a partly new experiment. That experiment relied on the conclusions from the literature hinting toward tasks with assumed attentional demands as particularly valuable in producing that effect. The finding from Study 2 that there is an ERP component not influenced by intention of hiding of one's actual sexual preference is also forensically relevant.

Moreover, findings from study 1 also showed how neuroelectric signals have already been used in courts to defend sexual assaults performed during sleep (sexsomnia). While ERP have not been used in this regard outside the area of sexsomnia Study 2 shows a potentially useful component (250-500 ms) that requires further research. Although Study 2 followed highly controlled laboratory preparations the study design using attentional tasks was still not suitable to make inferences about hidden sexual preferences at the single-subject level. A more

general problem beyond methodological comparability across studies still remains with regard to the interpretability of ERP signals. The detailed relation between, say, an EEG voltage amplitude, its underlying neurochemical structure, and the presumed associated mental (sexual) state was not a focus of the studies on sexuality identified in the literature.

3.3 Future directions

The use of neuroscience in forensic psychiatry seems imminent. It remains unlikely, however, that all legal concepts developed through human interactions will map onto the brain (Gazzaniga, 2005). Reconstructing the social history in a multigenerational way is still crucial in forensic assessments (Dudley & Leonard, 2008). There is also still a need for proper guidelines on how to adequately write reports when neuroimaging experts testify in criminal cases (Callahan & Barisa, 2004; Silva, 2007). Neuroscientific correlates of human behavior are often called into question because the putative causal direction is not established: Did behavior cause neurobiological abnormalities or was it the other way around? These questions would require longitudinal studies within the field of forensic psychiatry where access to participants is limited for several reasons. It was longitudinal research into brain development, though, that lead to a ban of the death penalty or mandatory life sentences for juveniles in the United States (Freedman & Zaami, 2019).

Looking specifically into sexual deviance, future studies should aim at replicating the PSW highlighted in Study 2 with methodological variations capable of achieving higher precision on a single-subject level. With a high enough accuracy such a test could be transferred to forensic setting where appropriate stimuli for a forensic outpatient group could be implemented in a longitudinal setting. Recidivism could then be compared to pre-recorded ERP. If high-arousal/negative valence picture content was used (e.g., images depicting violence), it should be acknowledged that Study 1 revealed that while sexually interesting pictures are

processed in specifically different ways in healthy individuals, in some studies this specificity was challenged by highly arousing and disturbing content.

Neuromodulation of sexual preference was only partly achieved in Study 3. It is difficult to relate the reduction of an attentional bias in the patient group to a modulation of sexual interest. This area is particularly in need of further research compared to the investigation into potential biomarkers for the diagnosis of sexual preference disorders. Establishing measurements for long-term therapeutic success will be another challenge for researchers.

3.4 Conclusion

The present work shows a first summary on an extensively researched field largely neglected by forensic-psychiatric research. Providing an evaluation of the current state of knowledge regarding neuroelectric correlates of human sexuality useful suggestions for a new experiment were drawn bypassing some of the methodological issues from the past. Furthermore, a potential biomarker for sexual preference in healthy subjects was suggested for further research. Neuroscience has already influenced legal and forensic evaluations. The intersection of law, offenders, and neuroscience seems promising but has also lead to new challenges and should place even stricter caveats on already old problems (e.g. admissibility of unestablished scientific techniques in criminal trials). The exact way in which neuroelectric signals measured from spatially diffusely defined cellular dipoles represent non-physical mental processes is still not understood. Yet such measurements have already entered the legal system and influenced judicial decisions on life and death at the highest instances. While these relations might never be fully understood it seems that accurate enough predictions might suffice in this context. This could both reflect the promising nature of such methods as well as the need for practically relevant methods in this context.

4. Publications

Article 1

Neuroelectric Correlates of Human Sexuality: A Review and Meta-analysis

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Article 2

Automaticity of early sexual attention: an ERP study

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Article 3

The Effects of Acute Transcranial Direct Current Stimulation on Attentional Bias in Pedophilic Disorder: A Pre-registered Pilot Study

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01.2014 – 04.2014	**Internship** at Psychiatric University Hospital Zurich, Division of Forensic Psychiatry
	Data acquisition through medical records & analysis, review of scientific literature and manuscripts, literature research
10.2013 – 02.2014	**Student Assistant** at the Division of Neuropsychology, Institute of Psychology, University of Zurich

	Recruitment, psychological testing, data acquisition & analysis
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10.2013 – 08.2014	**Student Assistant** at the Division of Psychopathology and Clinical Intervention, Institute of Psychology, University of Zurich
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